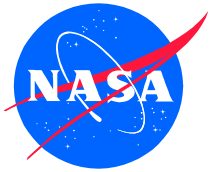
National Aeronautics and
Space Administration



Radiation Effects in Commercial GaN HEMT Devices

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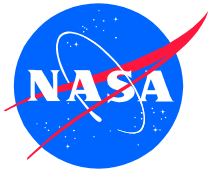
GaN-Based Devices



- GaN is a wide bandgap material that has received considerable interest in recent years
- Many potential applications:
  - High Temperature - >500C
  - High Power
  - RF frequencies
- Previous materials studies have suggested that GaN has a high radiation tolerance
- In this presentation, we take an initial look at the sensitivity of commercially available GaN devices to determine their radiation tolerance

Radiation Effects in Newly Available GaN MOSFETs and HEMTs- FY10 (New)

Rad-

Description:

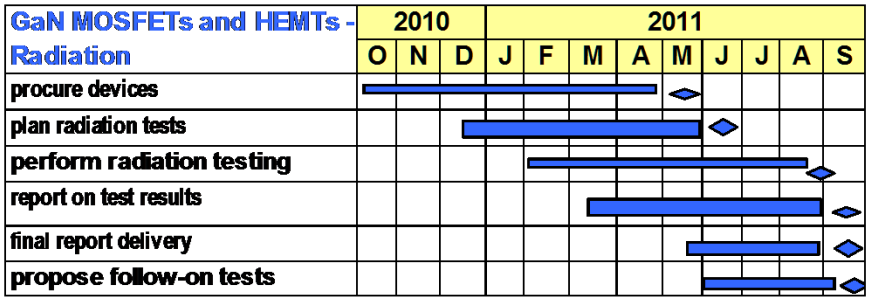
•Available power devices to NASA missions have decreased due to fabrication challenges at the manufacturer, but new technologies are coming onto the available market. Very little radiation test data applicable to NASA mission is available on these devices. Upcoming NASA missions have driven interest in a better catalogue of parts available to NASA designers and contractors with adequate mission assurance data.

•Device types for an emerging manufacture (EPC and Cree) will be procured pro bono to test to NASA standards (Testing Guideline for Single Event Gate Rupture (SEGR) of Power MOSFETs) for SEE and MIL-STD-883 1019. Applicability to NASA mission will be assess with any derating guidelines.

FY10 Plans:

- **Acquire parts**
  - **Devices from EPC, Cree**
- **Perform radiation testing**
  - **SEGR/B and TID/DDD**
- **Analyzed data**
  - **Side by side comparison with power MOSFETs**
  - **FIT and SER estimates**
  - **Any circuit application anomalies**
- **Report**

Schedule/Costs: Total Full-Cost = $100K



Deliverables:

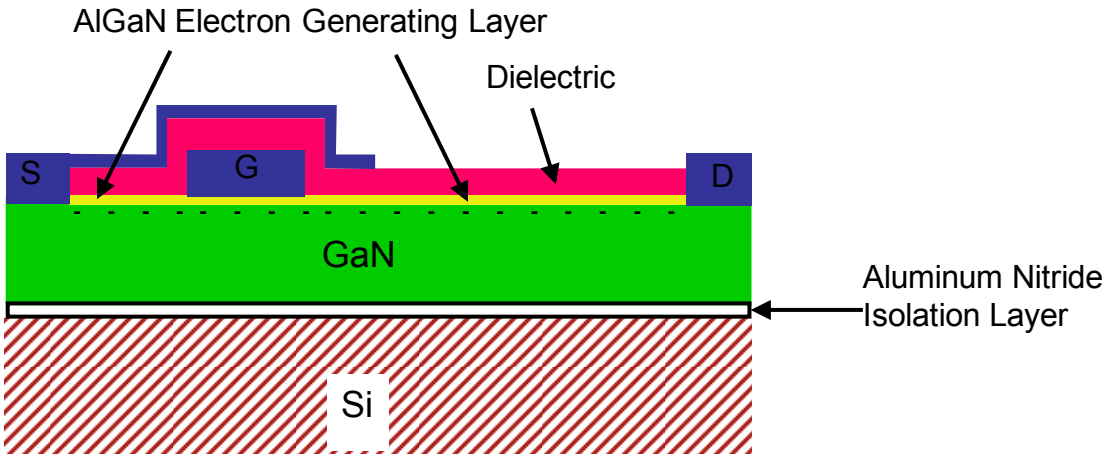
•Report on the radiation results for new device types (FY11)

NASA and Non-NASA Organizations/Procurements:

Lead Center/PI: JPL/Harris
Co-Is: JPL/Scheick
Contributors: None
Center Funding Split: 100%

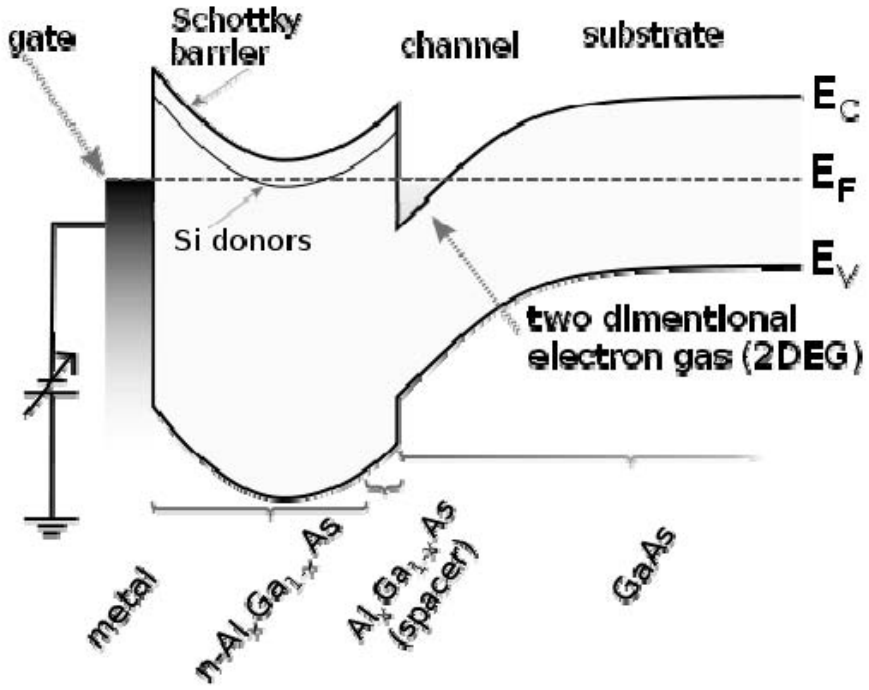
HEMT Device Structure

- Typical Structure of a GaN HEMT (High Electron Mobility Transistor) structure

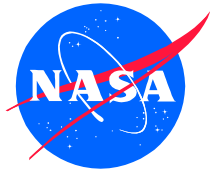


- Quantum well formed at the AlGaN/GaN heterojunction
- Results in conduction via a 2 dimension electron gas in this well
- Structure produces depletion mode devices (normally on)
- Negative gate voltage required to turn device off

Bandgap at Heterojunction Interface

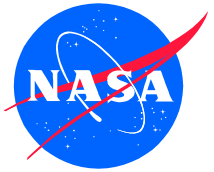


Initial Studies



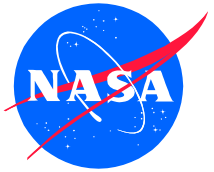
- SEB/SEGR
  - Tested at Texas A&M
  - Ions used:
    - Krypton – 953 MeV
    - Xenon – 2530, 738, 522, 391 MeV
- Proton Irradiation
  - Tested at UC Davis
  - 55 MeV protons
    - 1.6×10^{12} p/cm^2
    - Produces ~ 250 krad of TID
  - DC characteristics, only, measured in initial test

Parts Tested



Supplier	P/N	Power Level (W)	Max V_{DS} (V)	Date Code	Tests Performed
Cree	CGH40010FE	10	84	14609; 22209	Proton, SEB/SEGR
	CGH40025FE	25	84	16509	Proton
	CGH40120FE	120	84	02310	Proton, SEB/SEGR
Sumitomo	EGNB045MK	125	120	30RY; 30SM	Proton, SEB/SEGR
	EGNB010MK	45	120		SEB/SEGR
RFMD	RF3934200	120	48		SEB/SEGR

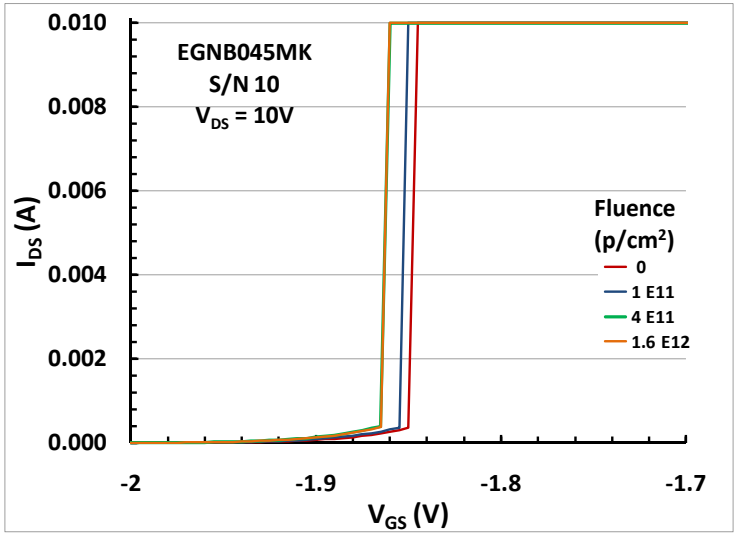
SEB/SEGR



- No deleterious effects were observed
  - Parts were delidded prior to test
  - Tested through angles up to 45 degrees
  - Parts showed high leakage current pre-irradiation
    - > 1 μA
  - Injected current observed to be small compared to leakage current

Proton Irradiation (DDD+TID)

- Threshold Voltage
  - Threshold determined from transfer characteristic

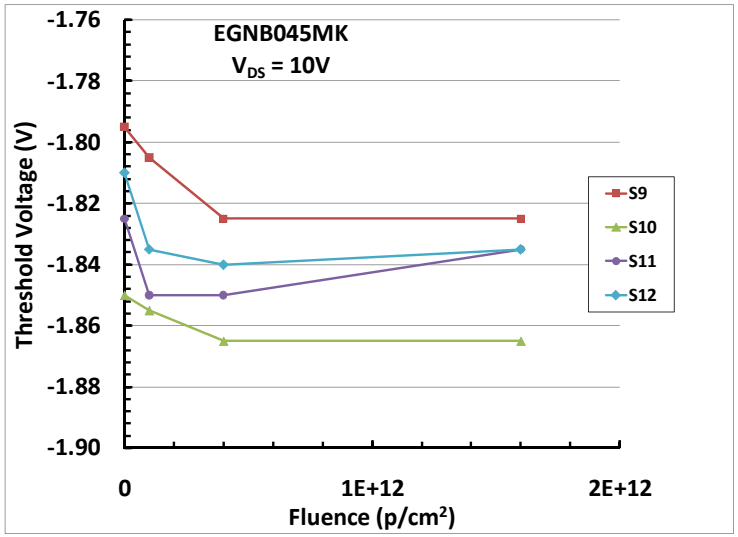


  - Typical transfer characteristic for a Sumitomo part with V_{DS} = 10V
  - Several fluences included

  - Transition from off-state to on-state is very abrupt
  - Threshold voltage taken to be the voltage of the last point in the off-state

Proton Irradiation (DDD+TID)

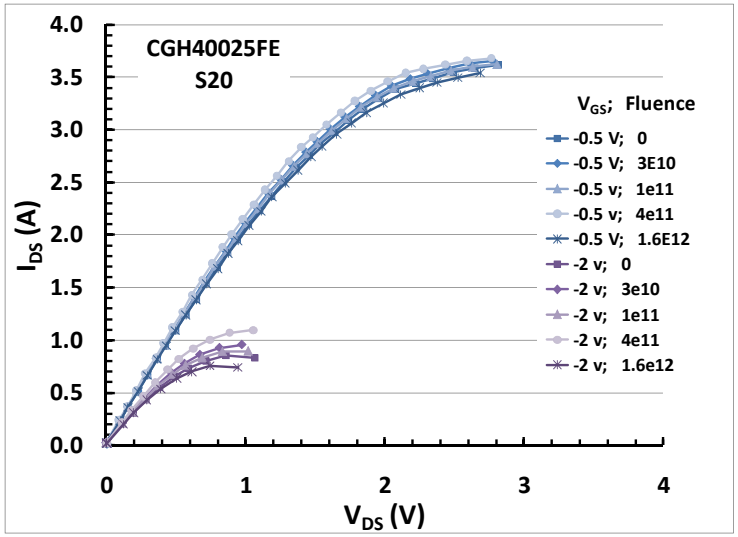
- Threshold Voltage (2)
  - 4 different Sumitomo parts



  - Appears to be a small decrease in the threshold voltage for the lower fluence levels
  - But at higher fluences no change for 2 parts and an increase for the other 2 parts
  - Conclude that there is at most a small change in V_{TH} with fluence and likely no real change
  - The Cree parts showed similar behavior with the values moving around some, but again with no unambiguous trend

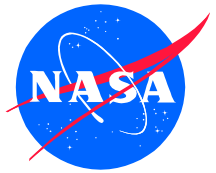
Proton Irradiation (DDD+TID)

- Output Characteristics
  - Typical result for a Cree part



  - No trend apparent for the different proton fluences
  - Conclude that there is at most a small change in VTH with fluence and likely no real change
  - The Cree parts showed similar behavior with the values moving around some, but again with no unambiguous trend

Discussion of Radiation Results



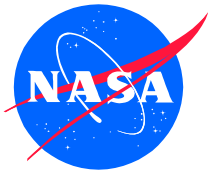
- SEB/SEGR
  - In HEMT device, the gate is a Schottky junction not an MOS-like structure
  - Nothing to rupture, so no SEGR

  - Leakage at gate is very high and injected current is small, so no SEB induced

- TID
  - No oxide in gate or other places, so no TID expected

- DDD
  - Expect DD degradation at sufficiently high fluences
  - These levels are moderate for a radiation hard material

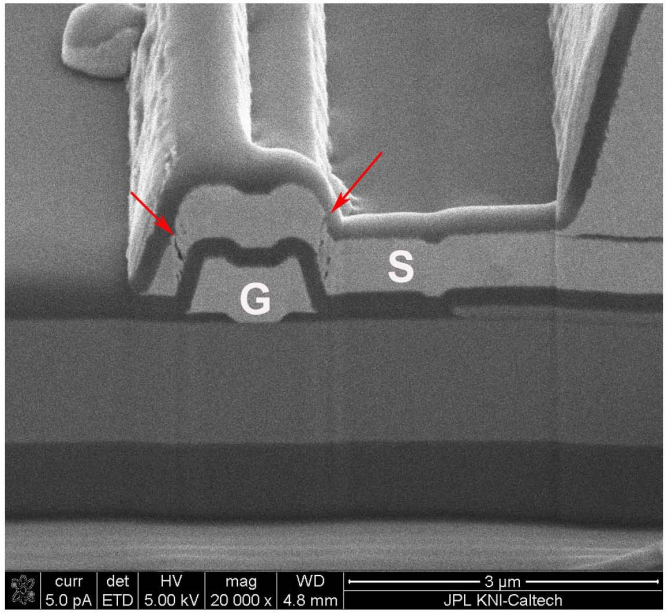
Follow-Up Plans



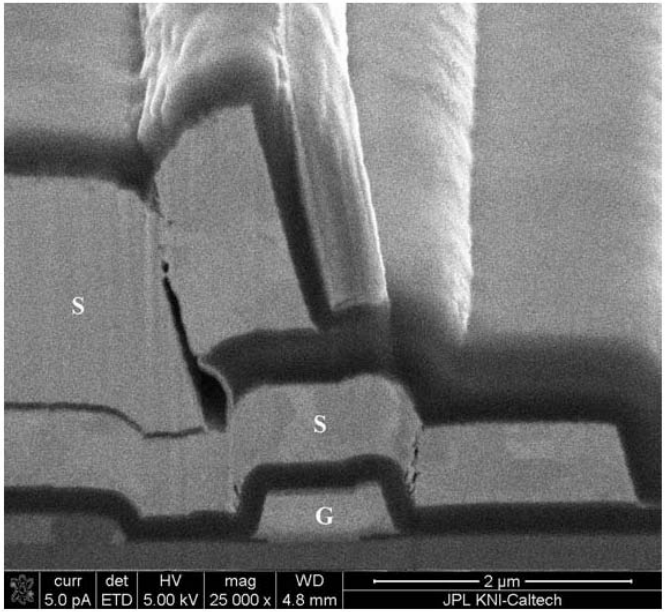
- Proton Irradiation
  - Another irradiation planned – last week of June
  - Measure additional parameters
    - DC
      - Output Characteristics
      - Saturated Drain Current
      - Threshold Voltage
      - Gate Quiescent Voltage
    - RF
      - Power Output
      - Small Signal Gain
      - Drain Efficiency
      - S-Parameters

Reliability Concerns

- Construction analysis performed including cross-sections, SEM, and FIB
  - Suppliers: Cree, Sumitomo, and RFMD
  - Most significant concern is voids in the metallization step coverage in Cree and RFMD parts

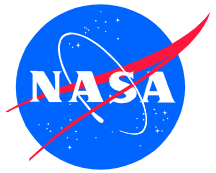


Cree



RFMD

Conclusion of Radiation Tests



- No significant degradation in DC parameters observed following the radiations used
- Includes
  - SEGR/SEB
  - TID (DC parameters only)
  - DDD (DC parameters only)
- Additional studies planned
  - Additional parameters
  - Other suppliers
    - In particular EPC (FY12?)
      - makes an enhancement mode (normally off) GaN device